Heraeus

High Performance Flexible Transparent Conductive Film

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- **Summary**

The Heraeus Group

- **Conductive Polymers Division** Acquired by Heraeus-December 1, 2010

  BAYER → H.C.Starck → Heraeus

- We are a global **precious metals and technology Group** with firm roots in Germany. The company has been **family-owned** for 160 years.
- Precious metals, sensors, electronic materials, biomaterials and medical products, dental products, quartz glass, and specialty light sources are the focus of our activities.
- Approximately 12,900 employees in over 120 subsidiaries.

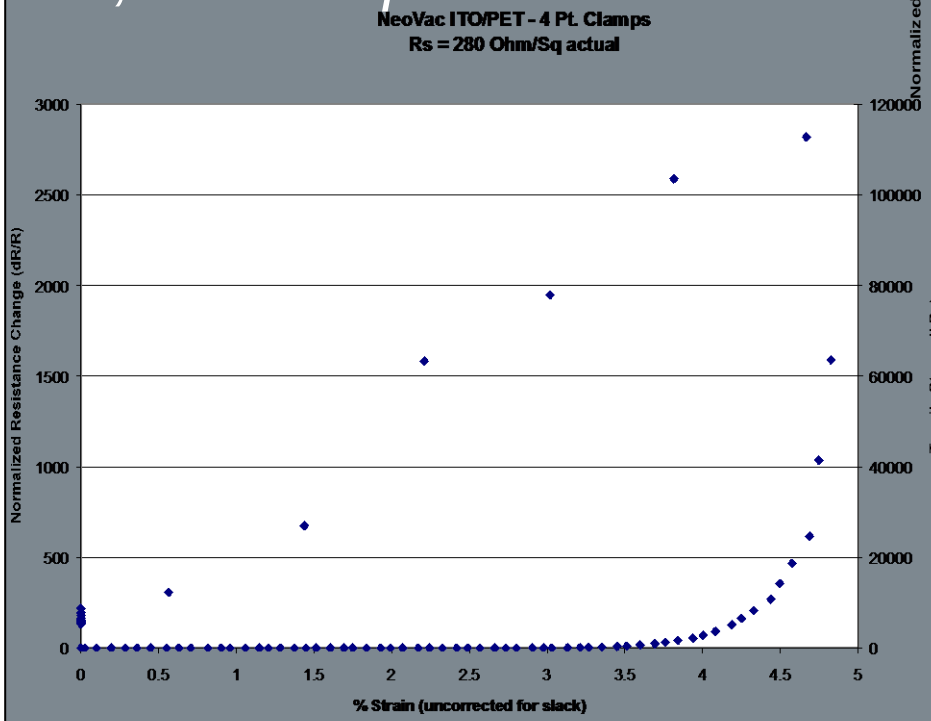
Opportunity

- **Address emerging opportunities for transparent conductive films with enhanced flexibility and durability**
- **ITO is well positioned for certain applications**
- **New devices will need improved performance**
  - **Improved physical properties**
  - **Improved cost control**

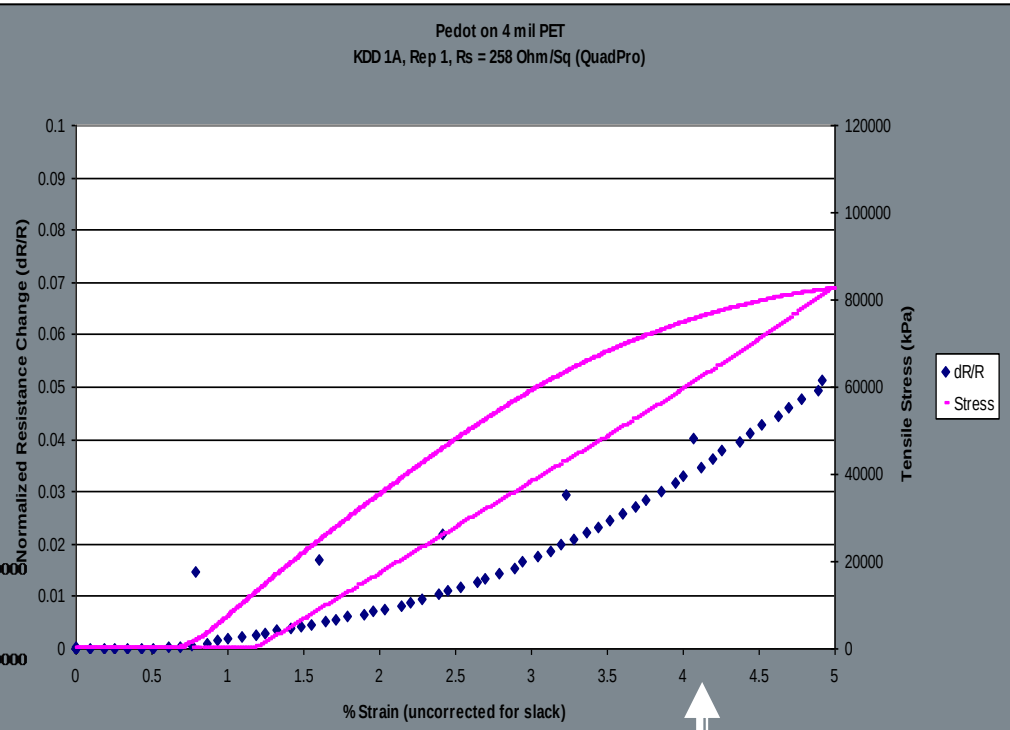
PEDOT vs. ITO – physical robustness*

Dramatic improvement in conductivity under strain

20,000 X improvement !



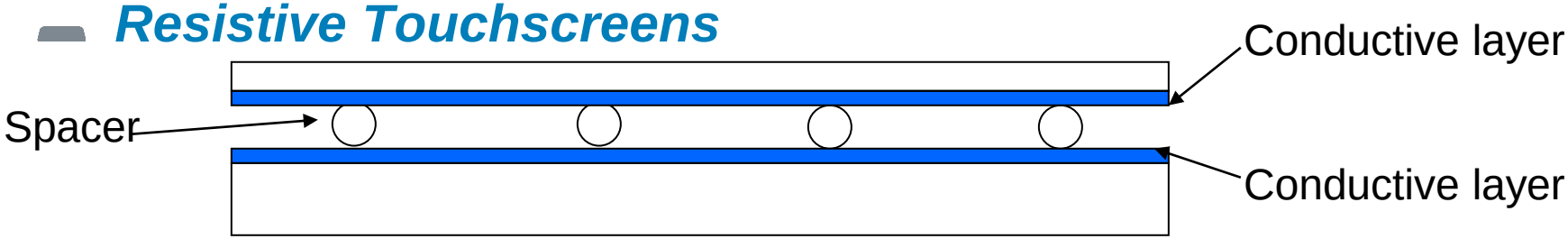
ITO/PET



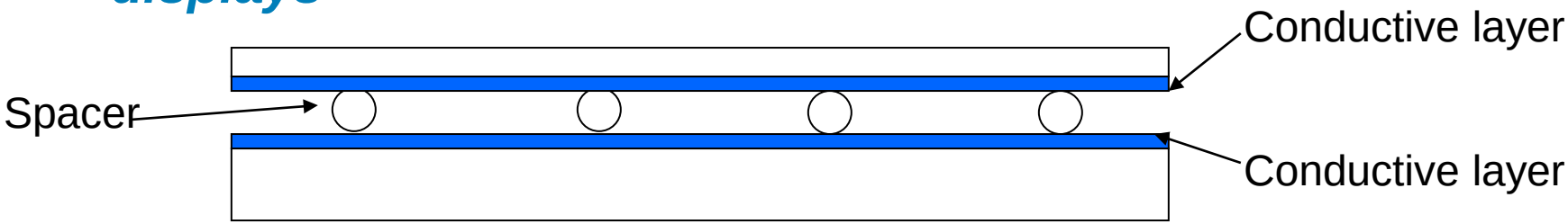
PEDOT/PET

Applications

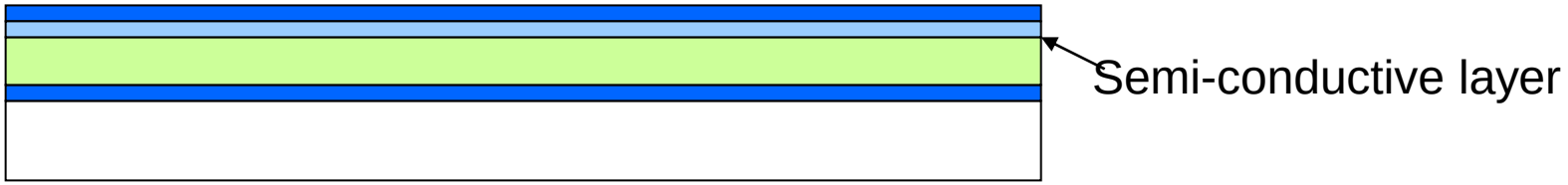
- ***Resistive Touchscreens***



- ***Conductive electrodes for Polymer dispersed LC (PDLC) displays***

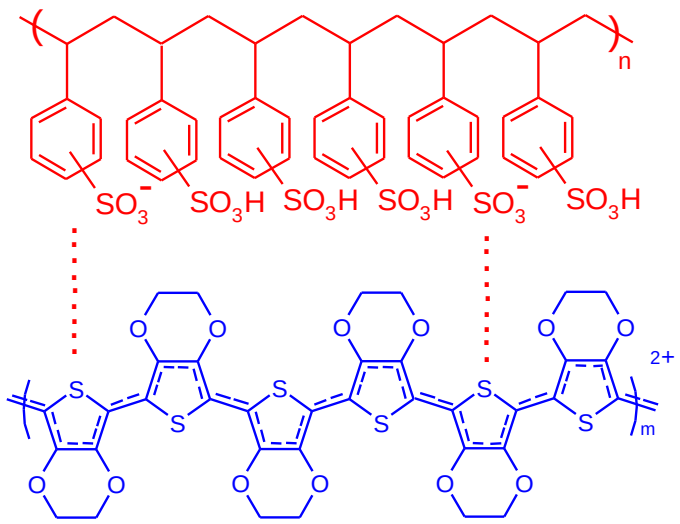


- ***Semi-conductive coatings on electrodes for PDLC displays***

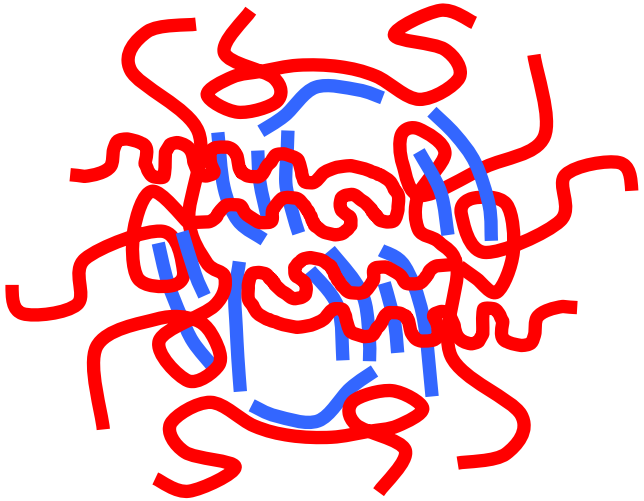


CLEVIOS™ PEDOT:PSS

- Water-based dispersion of the polymer complex poly(3,4-ethylenedioxythiophene)/ polystyrene sulfonate (PEDT/PSS or PEDOT/PSS)
- Submicrometer sized gel particles
- Produced at the Heraeus site in Leverkusen, Germany.
- Forms a continuous film upon drying



Chemical structure



Schematic picture of a dispersed gel particle

KODAK HCF Film ESTAR Base*

PEDOT

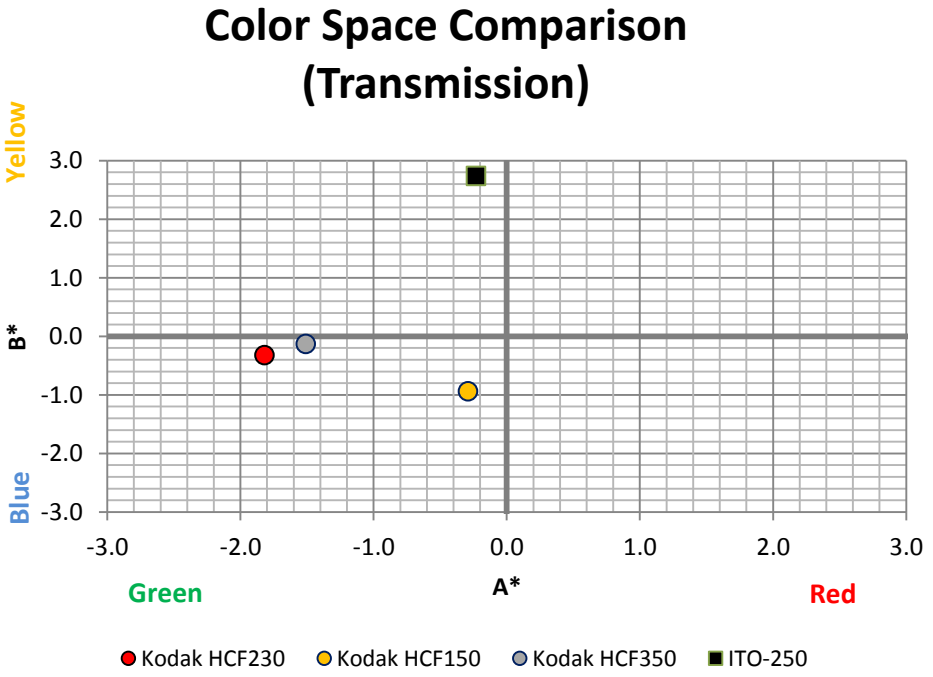
Primer

2.5 to 7 Mil Clear PET

Primer

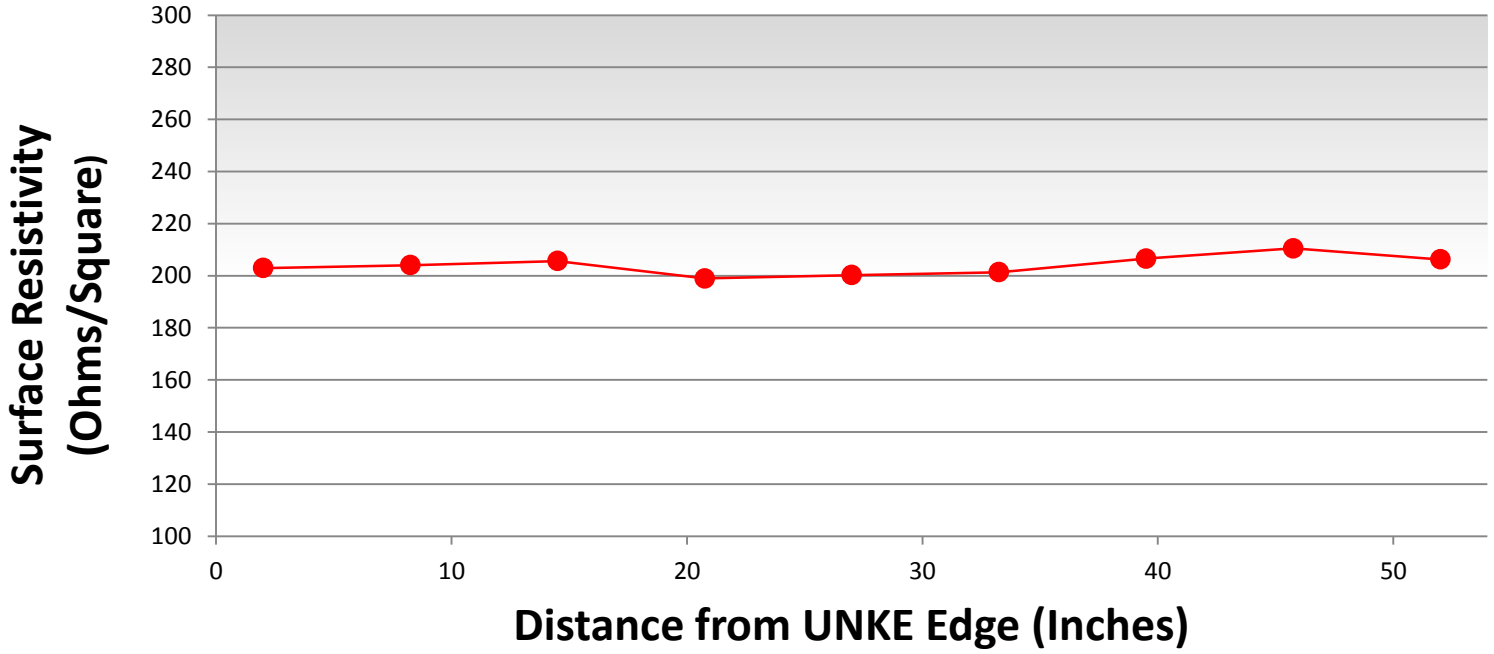
Optional functional layer

SR	VLT	Haze
150	86.2	0.89
230	88.3	0.83
350	91.7	0.92
250 (ITO)	87	1.02



*Data Courtesy of Eastman Kodak Company

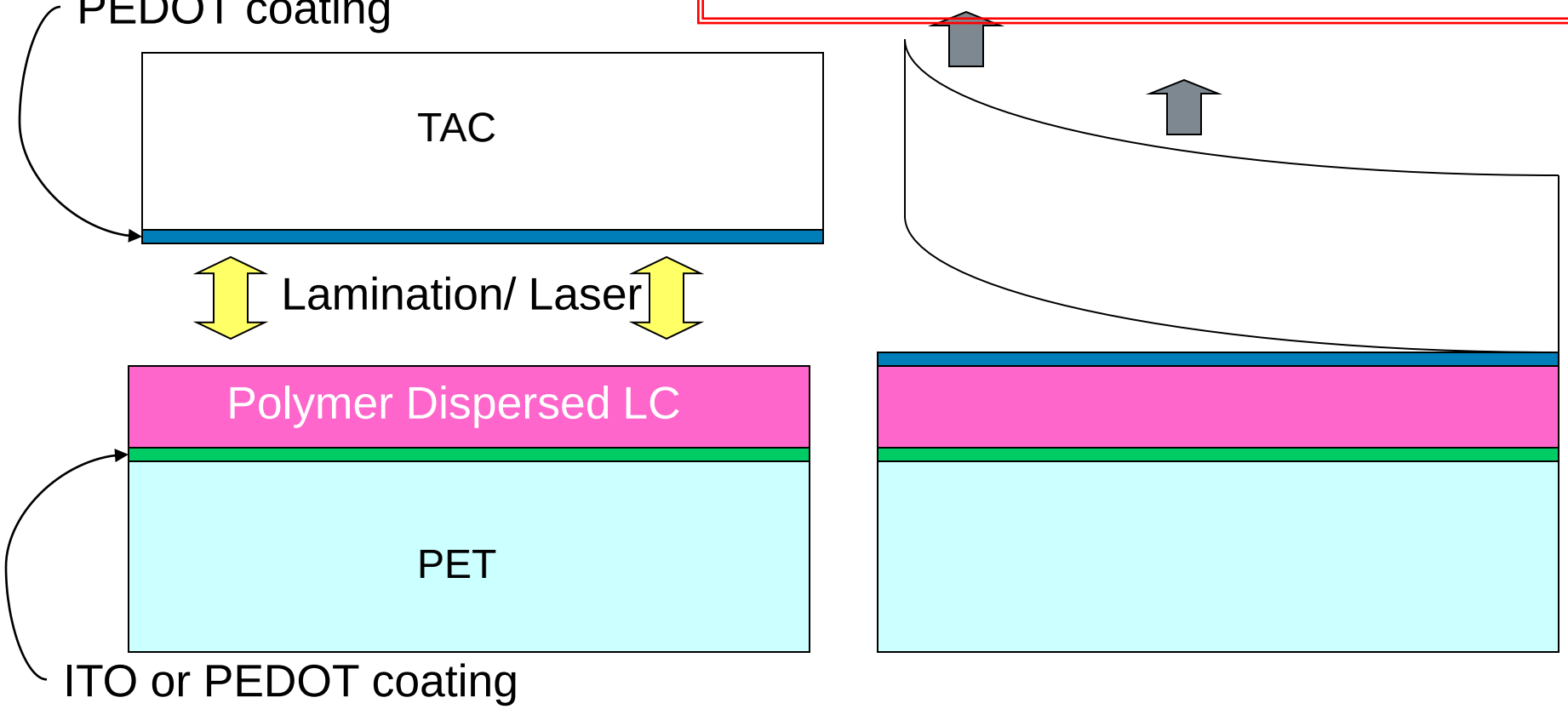
Cross-web Surface Resistivity Uniformity of PEDOT:PSS*



* Data Courtesy of Eastman Kodak Company

Dry-transfer of PEDOT*

- **Same SR before and after transfer**
- **Transfer without residue (ascertained by XPS)**
- **Surface roughness ~ 5nm (measured by AFM)**

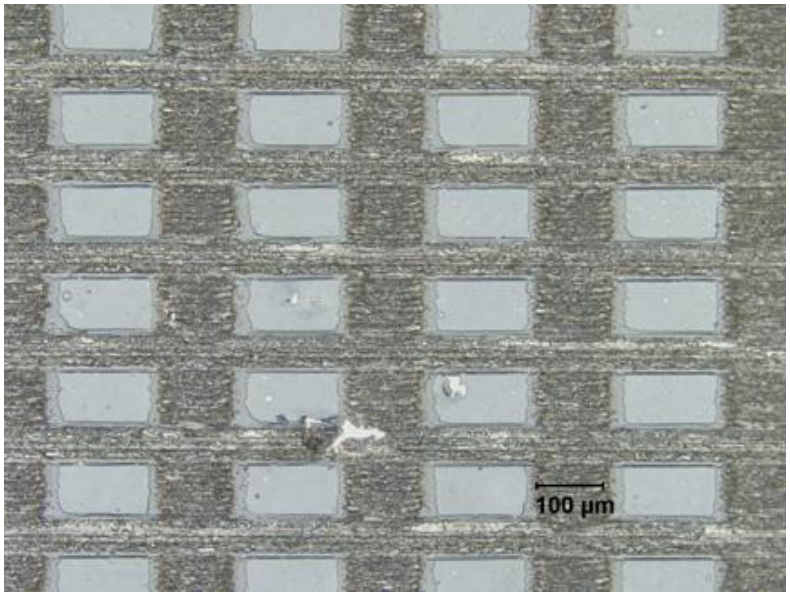


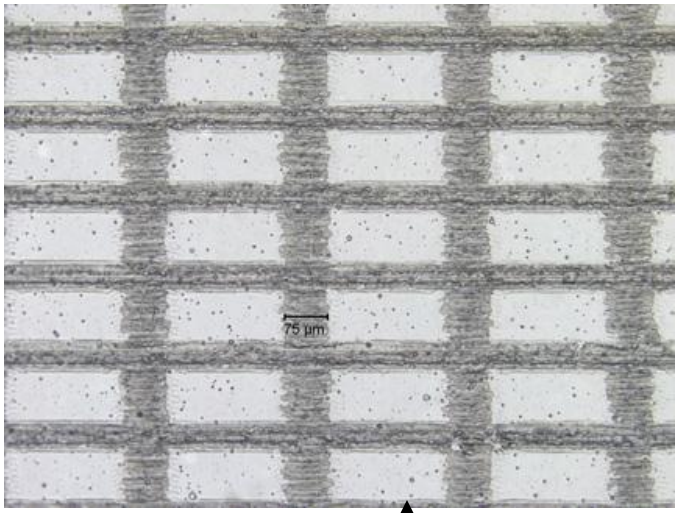
*Courtesy of Eastman Kodak Company

Laser Transfer of PEDOT*

SR ~ 600 ohms/square

Donor: PEDOT/TAC





Receiver: PVDC primed PET

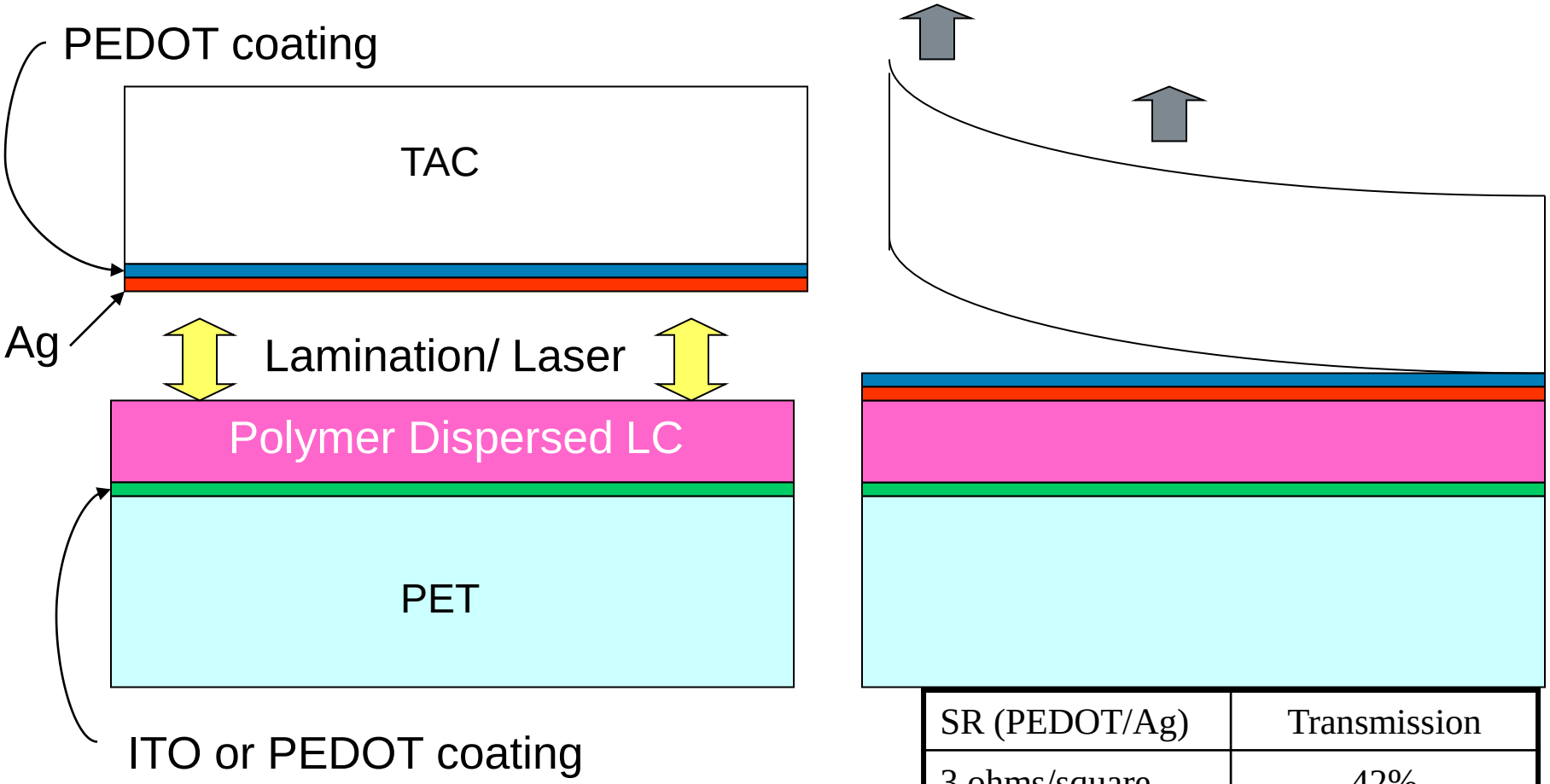
10 Hz 3.5 in scan

23 x 85 µm beam

3.4 J/cm^2

*Courtesy of Eastman Kodak Company

Dry-transfer of PEDOT and Silver*



SR (PEDOT/Ag)	Transmission
3 ohms/square	42%
7 ohms/square	58%
22 ohms/square	64%

Courtesy of Eastman Kodak Company

*Courtesy of Eastman Kodak Company

Challenges and Solutions

- **Environmental stability***

HCF 230	150C / 1h	85C / 85%RH 500h	60C / 90%RH 240h
232.5 ohm/sq	+1.4%	+6.8%	-2.7%

- **Electrical performance**
  - **Hybrid structure**

PEDOT:PSS Formulation for Conductive Electrodes

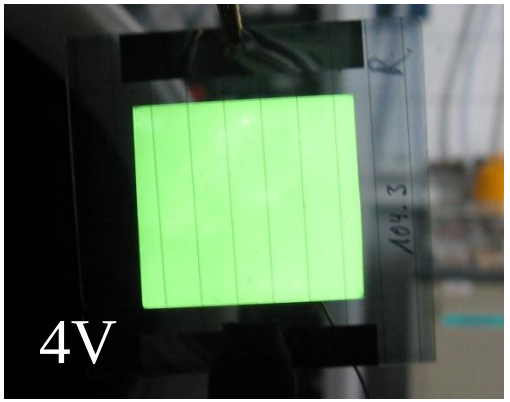
- A ready to use Clevios **F**ormulation for **C**onductive **E**lectrodes
- Smooth film formation over bus bars

Material properties	
Solids content	2.9%
Conductivity	120 S/cm
Viscosity	30 mPas [20°C]
Typical layer thickness	200 – 800 nm
Sheet resistance for 700 nm thick layer	85 Ohm/sq
Internal transmission for 700 nm thick layer	72 %

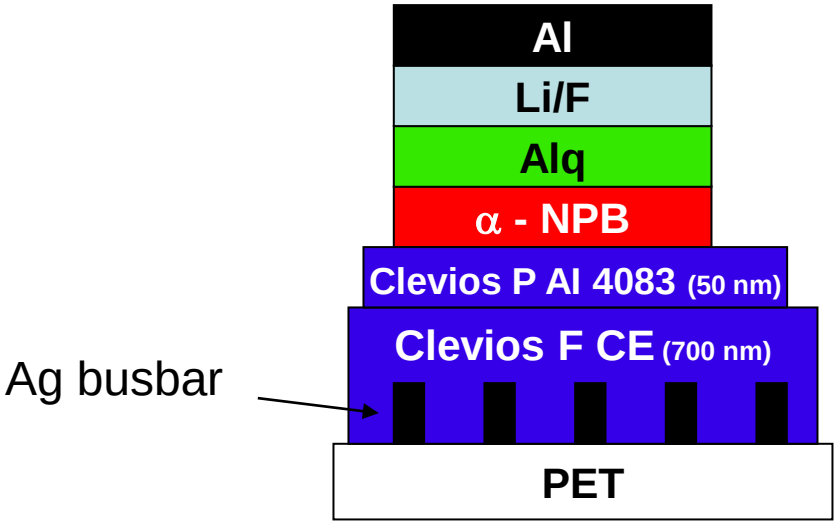
Typical values - not specifications

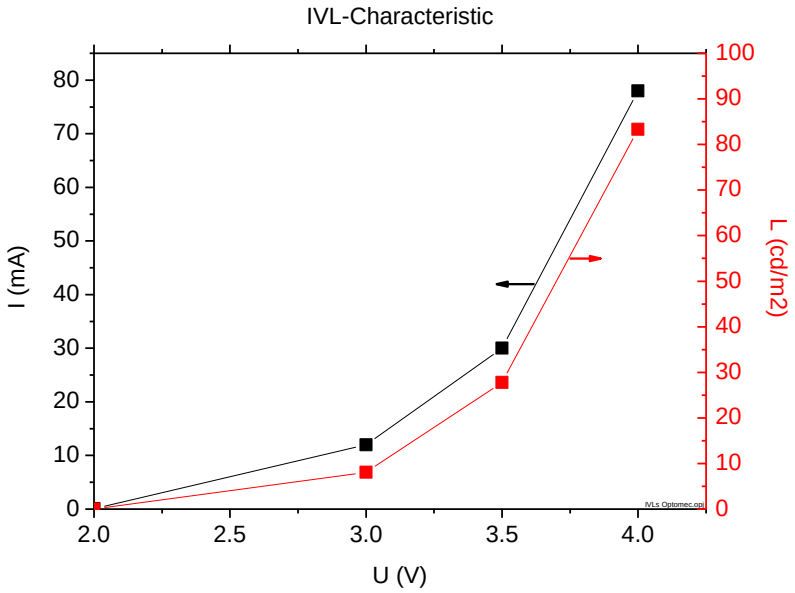
CLEVIOS™ F CE

- 12.5 cm^2 OLED on PET
- Low leakage current (I < 0.1 mA @ 1 V)
- Efficient device η = 1.0 cd/A



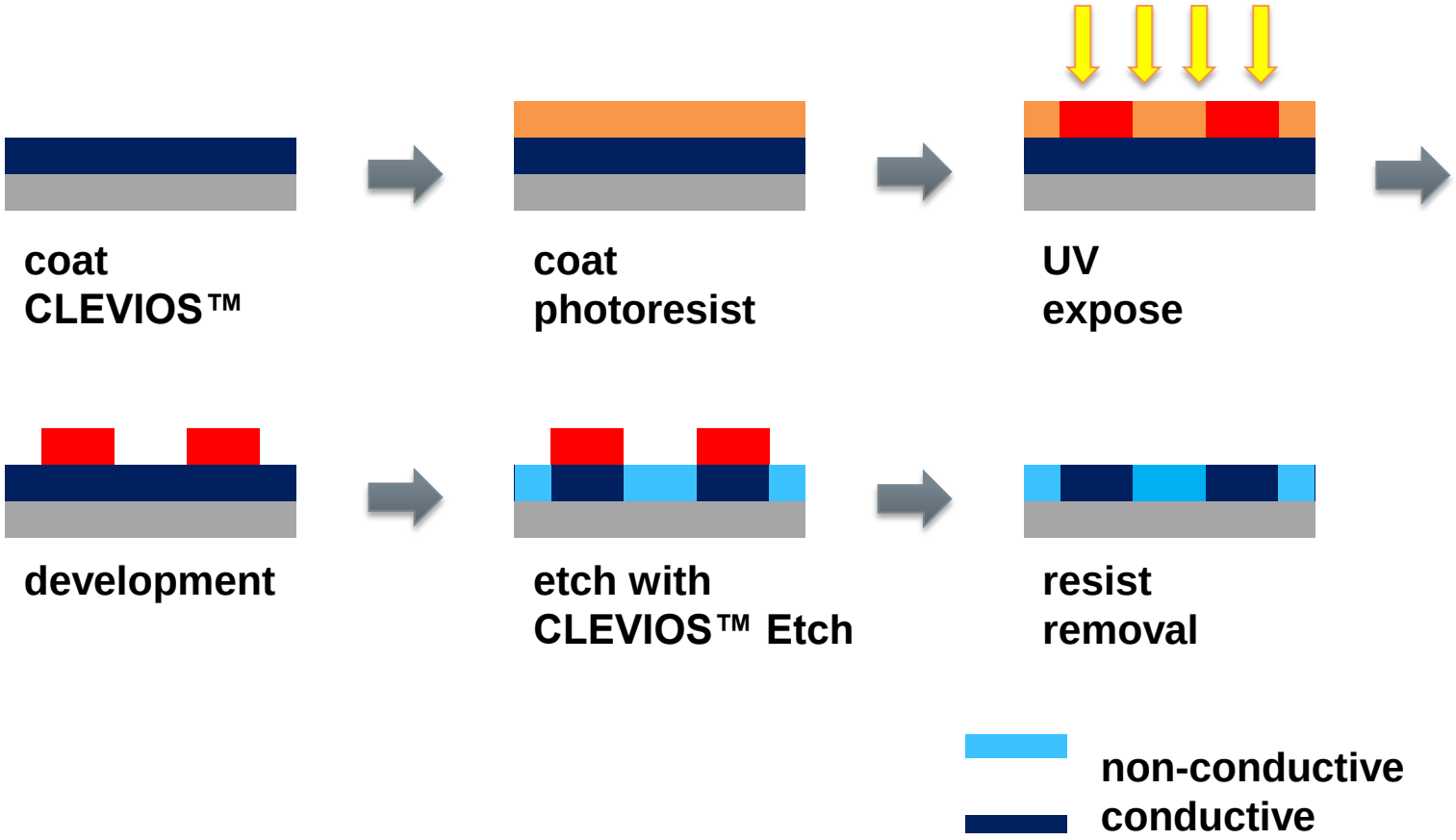
Ag-lines printed by OPTOMEC™





Invisible Wet ETCH Process

- Wet etching process specifically for CLEVIOS™ PEDOT:PSS films



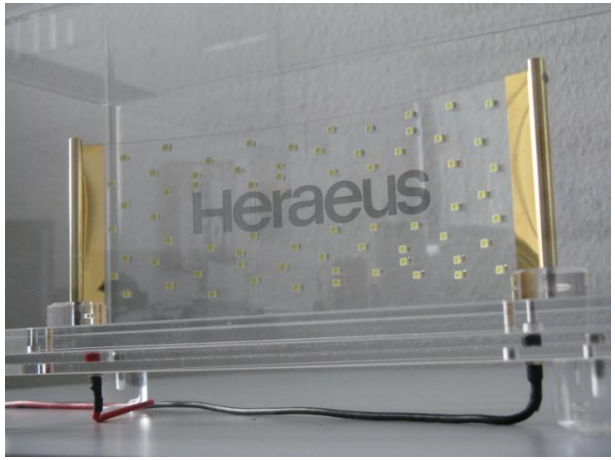
CLEVIOS™ ETCH

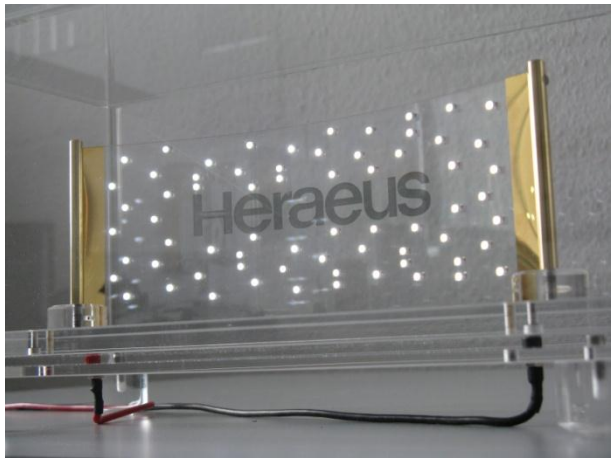
Properties	
Suitable solvent	water
Etching time	60 s (10% solution)
Surface resistance before etching	200 – 400 Ohm/sq
Surface resistance after etching	> 10^9 Ohm/sq

Easy Preparation:

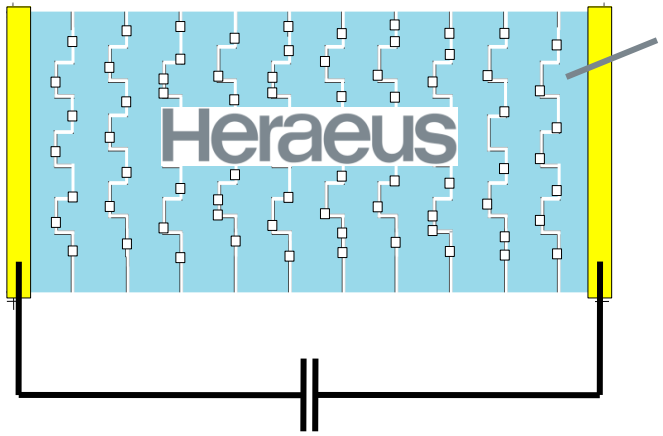
1) Dissolving 1 part Etchant in 9 parts of water
2) Stirring for 30 min
3) Filtration by 5 µm Polypropylene-Filter

Transparent Wire-Free LED-lighting





A **High Conductive PEDOT:PSS** coated curved PET-substrate has been structured into strips using **Clevios™ ETCH**.
The non-conductive and conductive areas have the same transparent appearance. The adjacent conductive segments are electrically bridged with LEDs. The result is clear illumination, with no apparent electrical connections.



Clevios™ FE-T

U_{DC} = 36V
I = 3mA

Advantages:
- Invisible structure
- Flexible
- Long term stability

Summary

- Cost Effective Opportunities Exist for Robust Flexible Alternative to ITO for Transparent Electrode Applications
- Multi-Roll to Roll Coating of PEDOT:PSS Demonstrated with Excellent Coating Uniformity and Environmental Stability
- Dry Transfer and Hybrid Structures of PEDOT:PSS for ITO-Free Devices
- Novel Invisible Wet-Etch Process for Patterning Transparent High Conductive Coatings of PEDOT:PSS

Acknowledgements

- Dr. Andreas Elschner, Mr. Udo Guntermann & Dr. Wilfried Lövenich - Heraeus Precious Metals GmbH & Co. KG-Conductive Polymers Division (Clevios)-Leverkusen, Germany
- HCF Team at Eastman Kodak in Rochester, NY

Building B 202 ChemPark Leverkusen